1.0 GENERAL

This Appendix presents information on representative values for parameters used in the computations. It is intended to serve as a reference that will permit the user to make preliminary estimates for use in a screening analysis, and for comparing local values against those developed from a broader data base.

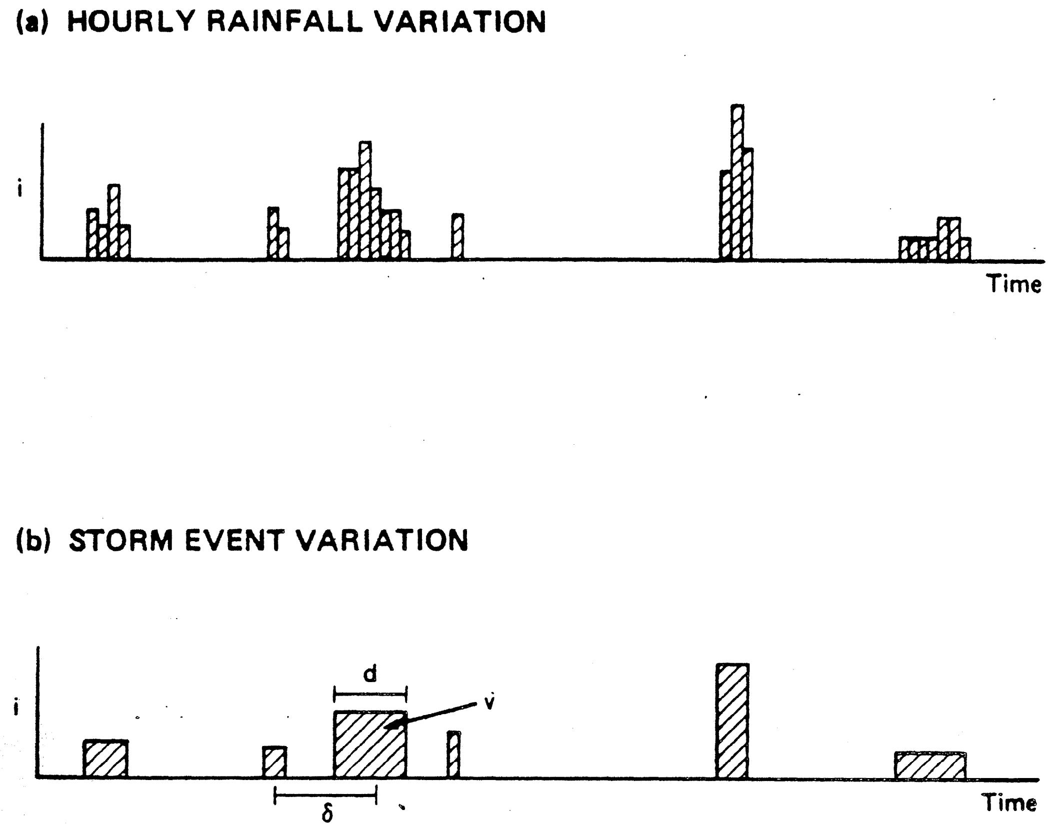
2.0 RAINFALL STATISTICS

Long-term rainfall patterns for an area are recorded in the hourly precipitation records of rain gages maintained by the U.S. Weather Service (USWS). The analysis procedures used in this manual are based on the statistical characteristics of storm "events." As illustrated by Figure A-1, the hourly record may be converted to an "event" record by the specification of a minimum number of dry hours that defines the separation of storm events. Routine statistical procedures are then used to compute the statistical parameters (mean, standard deviation, coefficient of variation) of all events in the record for the rainfall properties of interest.

A computer program, SYNOP, documented in a publication of EPA's Nationwide Urban Runoff Program (NURP), computes the desired statistics from rainfall data tapes obtainable from USWS. It generates outputs based on the entire record, and also on a stratification of the record by month, which is convenient for evaluating seasonal differences.

Table A-1 summarizes the statistics for storm event parameters for rain gages in selected cities distributed throughout the country. These data may be used to guide local estimates, pending analysis of specific data based on a site-specific rain gage. The tabulations provide values for mean and coefficient of variation for storm event volumes, average intensities, durations, and intervals between storm midpoints. The cities for which results have been tabulated are grouped by region of the country. Results are presented for both the long-term average of all storms, and for the June through September period that is often the critical period for receiving water impacts.

Figure A-2 provides initial estimates of storm event characteristics for broad regions of the country, based on data in the foregoing table.



	PARAMETER			
	For each storm event		For all storm events	
			Mean	Coef Var
Volume	v	(inches)	V	ν_v
Duration	d	(hours)	D	ν_d
Average intensity	i	(inch/hour)	I	ν_i
Interval between event midpoints	δ	(hours)	Δ	ν_δ

Figure A-1. Characterization of a rainfall record

Table A-1. RAINFALL EVENT CHARACTERISTICS FOR SELECTED CITIES

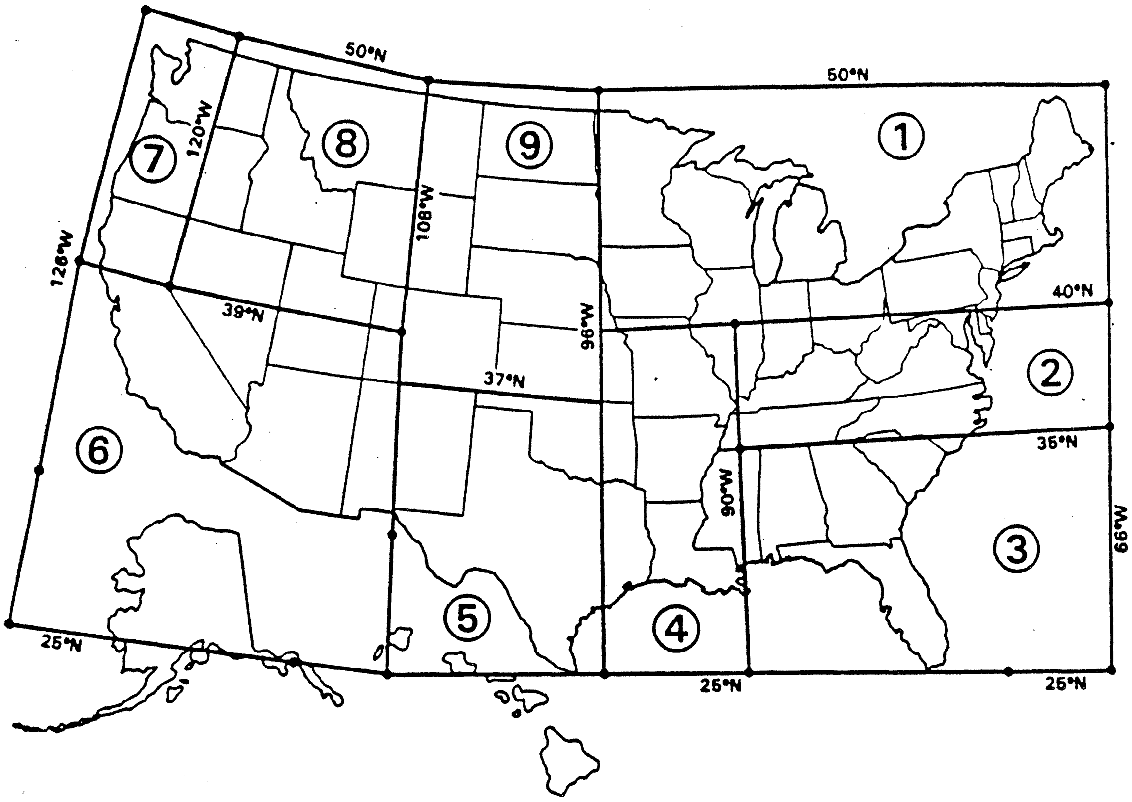
Location	Annual								June to September							
	Mean				Coefficient of Variation				Mean				Coefficient of Variation			
	V	I	D	Δ	ν_v	ν_i	ν_d	ν_Δ	V	I	D	Δ	ν_v	ν_i	ν_d	ν_Δ
Great Lakes																
Champaign-Urbana, IL	0.35	.063	6.1	80	1.47	1.37	1.02	1.02	0.45	.102	4.6	87	1.44	1.22	1.01	1.05
Chicago, IL (3)	0.27	.053	4.4	62	1.44	1.58	1.06	1.12	0.33	.091	6.2	67	1.49	1.37	1.00	1.13
Chicago, IL (5)	0.27	.053	5.7	72	1.59	1.54	1.08	1.00	0.37	.090	4.5	76	1.42	1.37	1.04	1.02
Davenport, IA	0.38	.077	6.6	98	1.37	1.24	1.40	1.01	0.49	.112	5.3	91	1.32	1.14	1.22	0.94
Detroit, MI	0.21	.050	4.4	57	1.59	1.16	1.02	1.07	0.27	.095	3.1	64	1.43	1.32	0.82	1.14
Louisville, KY	0.38	.064	6.7	76	1.45	1.42	1.08	1.00	0.36	.094	4.5	78	1.40	1.31	1.01	1.04
Minneapolis, MN	0.24	.043	6.0	87	1.48	1.22	1.08	0.98	0.34	.075	4.5	74	1.34	1.26	1.00	0.92
Steubenville, OH	0.31	.057	7.0	79	1.28	1.03	1.39	1.00	0.39	.094	5.9	88	1.28	1.27	1.76	0.95
Toledo, OH	0.22	.048	5.0	62	1.52	1.16	0.99	1.03	0.29	.083	3.7	69	1.43	1.37	1.93	1.06
Zanesville, OH	0.30	.061	6.1	77	1.24	1.01	0.93	1.03	0.36	.100	4.3	80	1.23	1.11	0.95	1.06
Lansing, MI (5)(30 yr)	0.21	.041	5.6	62	1.56	1.55	1.10	1.02	0.29	.073	4.2	71	1.39	1.25	0.98	1.00
Lansing, MI (5)(21 yr)	0.26	.047	6.2	87	1.42	1.42	0.95	1.00	0.34	.078	5.1	89	1.25	1.13	0.90	0.98
Ann Arbor, MI (5)																
Lower Mississippi Valley																
Memphis, TN	0.52	.086	6.9	89	1.36	1.31	1.07	1.01	0.44	.112	4.7	88	1.35	1.28	1.12	1.06
New Orleans, LA (8)	0.61	.113	6.9	89	1.46	1.40	1.24	1.02	0.53	.142	5.0	65	1.40	1.42	1.34	1.08
Shreveport, LA (9)(17 yr)	0.54	.080	7.8	110	1.39	1.27	1.09	0.99	0.49	.105	5.3	109	1.50	1.27	1.28	1.09
Lake Charles, LA (10)	0.66	.108	7.7	109	1.64	1.40	1.26	0.99	0.63	.130	5.9	86	1.90	1.41	1.43	0.99
Average	0.58	.097	7.3	99	1.46	1.35	1.17	1.00	9.52	.122	5.2	87	1.54	1.35	1.29	1.06
Texas																
Abilene, TX	0.32	.083	4.2	128	1.52	1.24	1.01	1.45	0.42	.121	3.3	114	1.56	1.32	0.98	1.46
Austin, TX	0.33	.078	4.0	96	1.88	1.53	1.06	1.44	0.38	.106	3.3	108	1.82	1.71	1.02	1.49
Brownsville, TX	0.27	.072	3.5	1.09	2.02	1.43	1.20	1.50	0.33	.104	2.8	101	1.94	1.33	1.30	1.67
Dallas, TX	0.39	.079	4.2	100	1.64	1.23	1.00	1.32	0.38	.100	3.2	111	1.65	1.24	1.01	1.44
Waco, TX	0.36	.086	4.2	1.06	1.66	1.40	1.08	1.36	0.40	.117	3.3	124	1.60	1.34	1.07	1.39
Average	0.33	0.080	4.0	108	1.74	1.37	1.07	1.41	0.38	.110	3.2	112	1.71	1.39	1.08	1.49

Table A-1. RAINFALL EVENT CHARACTERISTICS FOR SELECTED CITIES (continued)

	Annual								June to September							
	Mean				Coefficient of Variation				Mean				Coefficient of Variation			
Location	V	I	D	Δ	ν_v	ν_i	ν_d	ν_Δ	V	I	D	Δ	ν_v	ν_i	ν_d	ν_Δ
Northeast																
Caribou, ME	0.21	.034	5.8	55	1.58	0.97	1.03	1.03	0.24	.054	4.4	55	1.64	1.15	1.00	1.01
Boston, MA	0.33	.044	6.1	68	1.67	1.02	1.03	1.06	0.30	.063	4.2	73	1.80	1.20	1.12	1.12
Lake George, NY	0.23	.067	5.4	76	1.26	1.98	0.91	1.48	0.27	.076	4.5	72	1.25	1.61	0.86	1.44
Kingston, NY	0.37	.052	7.0	80	1.35	1.01	0.91	0.98	0.35	.073	5.0	79	1.46	1.27	1.00	1.08
Poughkeepsie, NY	0.35	.052	6.9	81	1.31	0.95	0.87	0.95	0.36	.081	4.9	82	1.48	1.16	0.96	1.00
New York City, NY	0.37	.053	6.7	77	1.37	1.04	0.93	0.89	0.30	.076	4.8	75	1.51	1.28	1.03	0.95
Mineola LI, NY	0.43	.088	5.8	89	1.34	1.14	1.30	0.99	0.41	.114	4.5	88	1.42	1.17	1.48	1.03
Upton LI, NY	0.43	.076	6.3	81	1.42	1.06	1.09	0.99	0.42	.101	4.6	88	1.56	1.10	1.23	1.02
Wantagh LI, NY (2 YR)	0.40	.075	5.6	83	1.54	1.24	1.03	1.03	0.34	.091	4.0	74	1.59	1.08	1.28	0.99
Long Island, NY	0.41	.126	4.2	93	1.35	1.30	1.12	1.72	0.41	.127	3.4	99	1.52	1.15	1.21	1.57
Washington, D.C.	0.36	.067	5.9	80	1.45	1.18	1.03	1.00	0.41	.107	4.1	78	1.67	1.38	1.10	1.06
Baltimore, MD (3)	0.40	.069	6.0	82	1.48	1.21	1.01	1.03	0.43	.107	4.2	79	1.66	1.49	1.08	1.08
Southeast																
Greensboro, NC	0.32	.067	5.0	67	1.40	1.44	1.11	1.18	0.34	.093	3.6	62	1.67	1.43	1.20	1.19
Columbia, SC	0.38	.102	4.5	68	1.55	1.59	1.13	1.18	0.41	.153	3.4	58	1.59	1.68	1.25	1.13
Atlanta, GA	0.50	.074	8.0	94	1.37	1.16	1.11	0.93	0.45	.100	6.2	87	1.43	1.27	1.31	0.97
Birmingham, ALA	0.53	.086	7.2	85	1.44	1.31	1.09	1.00	0.45	.111	5.0	76	1.47	1.33	1.18	1.01
Gainesville, FLA	0.64	.139	7.6	106	1.35	1.14	1.66	1.06	0.65	.161	6.6	70	1.41	1.13	1.65	0.92
Tampa, FLA	0.40	.110	3.6	93	1.63	1.21	1.11	1.10	0.44	.138	3.1	49	1.70	1.28	1.28	1.01
Average	0.49	.102	6.2	89	1.47	1.28	1.22	1.05	0.48	.133	4.9	68	1.52	1.34	1.33	1.01

Table A-1. RAINFALL EVENT CHARACTERISTICS FOR SELECTED CITIES (concluded)

	Annual								June to September							
	Mean				Coefficient of Variation				Mean				Coefficient of Variation			
Location	V	I	D	Δ	ν_ν	ν_i	ν_d	ν_Δ	V	I	D	Δ	ν_ν	ν_i	ν_d	ν_Δ
Rocky Mountains																
Denver, CO (3) 8 YRS	0.15	.033	4.3	97	2.00	1.58	1.24	1.25	0.18	.053	3.2	82	1.90	1.44	1.20	1.26
Denver, CO (3) 25 YRS	0.15	.033	4.8	101	1.73	1.07	1.20	1.15	0.15	.055	3.2	80	1.85	1.51	1.20	1.05
Denver, CO (13) 24 YRS	0.22	.032	9.1	144	1.49	1.13	1.15	0.92	0.22	.053	4.4	101	1.78	1.53	1.35	0.23
Rapid City, SD (3)	0.15	.039	4.0	86	1.81	1.63	1.21	1.33	0.20	.063	3.0	75	1.63	1.36	1.08	1.20
Rapid City, SD (12)	0.20	.033	8.0	127	1.46	1.09	1.24	0.95	0.25	.059	6.1	101	1.50	1.46	1.39	0.94
Salt Lake City, UT (3)	0.14	.031	4.5	94	1.42	0.91	0.92	1.39	0.14	.041	2.8	125	1.51	1.13	0.80	1.41
Salt Lake City, UT (3) (2 GAGES)	0.18	.025	7.8	133	1.32	1.06	0.85	0.97	0.16	.031	6.8	164	1.43	1.06	1.01	0.98
Average (2)	0.15	.036	4.4	94	1.77	1.35	1.20	1.24	0.18	.059	3.1	78	1.74	1.44	1.14	1.13
California																
Oakland, CA	0.19	.033	4.3	320	1.62	0.74	1.03	1.60	0.11	.020	2.9	756	1.63	0.56	1.00	1.09
San Francisco, CA (75)	0.78	.017	59	515	1.45	0.89	1.37	0.72	0.14	.017	11.2	830	1.46	0.70	1.67	0.75
Southwest																
El Paso, TX	0.15	.047	3.3	226	1.54	1.12	1.07	1.43	0.19	.069	2.6	142	1.68	1.28	1.20	1.44
Phoenix, AZ	0.17	.055	3.2	286	1.38	1.26	0.97	1.42	0.21	.090	2.4	379	1.51	1.64	0.84	1.25
Average	0.17	.045	3.6	277	1.51	1.04	1.02	1.48	0.17	.060	2.6	425	1.61	1.16	1.01	1.26
Northwest																
Portland, OR (3) 25 YRS	0.17	.017	5.4	60	1.60	0.85	1.00	1.47	0.15	.019	4.5	109	1.45	0.99	0.95	1.64
Portland, OR (10) 10 YRS	0.36	.023	15.5	83	1.51	0.79	1.09	1.32	0.22	.027	9.4	179	1.32	1.33	1.13	1.20
Eugene, OR (6)	0.39	.030	10.9	73	1.85	0.87	1.25	1.74	0.21	.033	6.3	167	1.32	1.01	1.05	1.49
Eugene, OR (15)	0.63	.026	23.1	118	1.88	0.88	1.35	1.30	0.28	.029	12.0	226	1.28	1.07	1.72	1.20
Eugene, OR (20)	0.72	.025	29.2	136	1.85	0.91	1.34	1.19	0.31	.027	15.0	250	1.24	1.15	1.19	1.11
Seattle, WA (15)	0.46	.023	21.5	101	1.45	0.86	1.26	1.02	0.29	.024	12.7	159	1.45	0.92	1.24	1.04
Average	0.48	.024	20.0	101	1.61	0.84	1.23	1.21	0.26	.027	11.4	188	1.35	1.11	1.20	1.15



ZONE	PERIOD	RAINFALL STATISTICS							
		VOLUME (IN)		INTENSITY (IN/HR)		DURATION (HR)		INTERVAL (HR)	
		MEAN	C.V.	MEAN	C.V.	MEAN	C.V.	MEAN	C.V.
1	ANNUAL	0.26	1.46	0.051	1.31	5.8	1.05	73	1.07
	SUMMER	0.32	1.38	0.082	1.29	4.4	1.14	76	1.07
2	ANNUAL	0.36	1.45	0.066	1.32	5.9	1.05	77	1.05
	SUMMER	0.40	1.57	0.101	1.37	4.2	1.09	77	1.08
3	ANNUAL	0.49	1.47	.102	1.28	6.2	1.22	89	1.05
	SUMMER	0.48	1.52	.133	1.34	4.9	1.33	68	1.01
4	ANNUAL	0.58	1.46	.097	1.35	7.3	1.17	99	1.00
	SUMMER	0.52	1.54	.122	1.35	5.2	1.29	87	1.06
5	ANNUAL	0.33	1.74	.080	1.37	4.0	1.07	108	1.41
	SUMMER	0.38	1.71	.110	1.39	3.2	1.08	112	1.49
6	ANNUAL	0.17	1.51	.045	1.04	3.6	1.02	277	1.48
	SUMMER	0.17	1.81	.060	1.16	2.6	1.01	425	1.26
7	ANNUAL	0.48	1.81	0.024	0.84	20.0	1.23	101	1.21
	SUMMER	0.26	1.35	0.027	1.11	11.4	1.20	188	1.15
8	ANNUAL	0.14	1.42	.031	0.91	4.5	0.92	94	1.39
	SUMMER	0.14	1.51	.041	1.13	2.8	0.80	125	1.41
9	ANNUAL	0.15	1.77	.036	1.35	4.4	1.20	94	1.24
	SUMMER	0.18	1.74	.059	1.44	3.1	1.14	78	1.13

Figure A-2. Representative regional values for preliminary estimates

From the statistics of the storm event parameters, other values of interest may be determined.

The ratio of mean storm duration (D), to the mean interval between storms (Δ), reflects the percent of the time that storm events are in progress:

$$\% \text{ time that it is raining} = \frac{D}{\Delta}$$

The average number of storms during any period of time is defined by the ratio between the total number of hours in the selected period and the average interval between storms (Δ). For example, on an annual basis:

$$\text{Avg. number of storms per year} = \frac{365 * 24}{\Delta}$$

The storm event parameters of interest have been shown to be well represented by a gamma distribution, and the results listed in Table A-1 indicate that the coefficient of variation of the event parameters generally falls between 1.0 and 1.5. Figure A-3 plots the probability distribution of gamma distributed variables with coefficients of variation of 1.0, 1.25, and 1.5, in terms of probability of occurrence as a function of the magnitude, expressed as a multiple of the mean. This plot can be used to approximate the magnitude of an event with a specified frequency of occurrence.

For example, consider a site where storm events have volume statistics for mean and coefficient of variation of 0.4 inch, and 1.5 respectively. Figure A-3 can be used to estimate that 1 percent of all storm events have volumes that exceed about 7.5 times the mean (or 7.5 * 0.4 = 3 inches). If the same location has an average interval between storms (Δ) of 87.5 hours, there will be an average of:

$$(365 * 24) / 87.5 = 100 \text{ events/year}$$

and the 1 percentile event (3 inches) reflects a storm volume exceeded on average, once per year.

3.0 RUNOFF COEFFICIENT (Rv)

Runoff coefficient is defined as the fraction of rainfall that appears as surface runoff. The substantial data base developed under EPA's NURP program indicated that runoff coefficient varied from event to event at any site. Variations were not significantly correlated with storm size or intensity and can be treated as random. The median value for a site was best estimated by the percent of impervious surface in the drainage area.

Figure A-4 illustrates the relationship between the median runoff coefficient observed at an urban site and the percent of impervious area in the catchment.

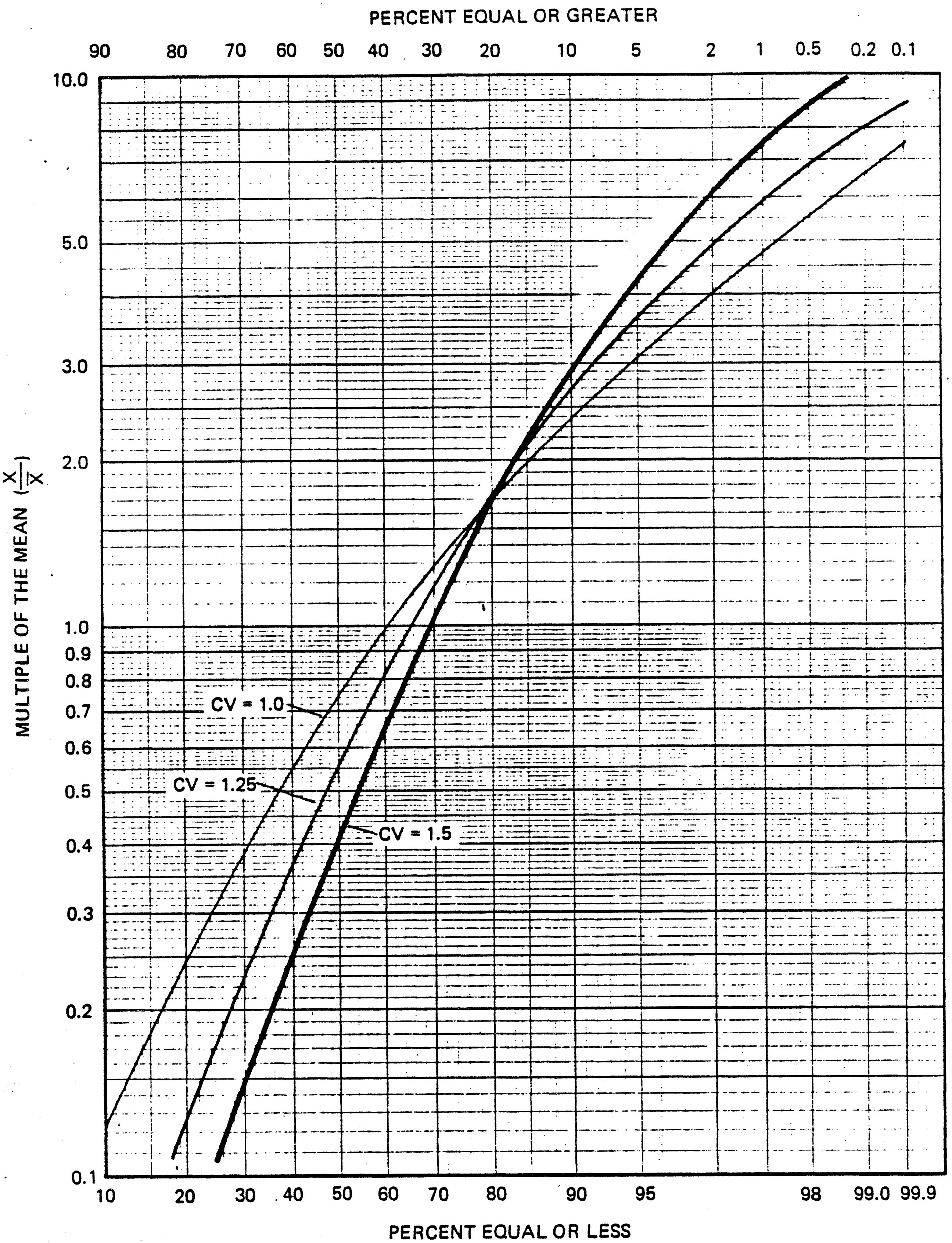


Figure A-3. Probability distribution for a variable with a gamma distribution

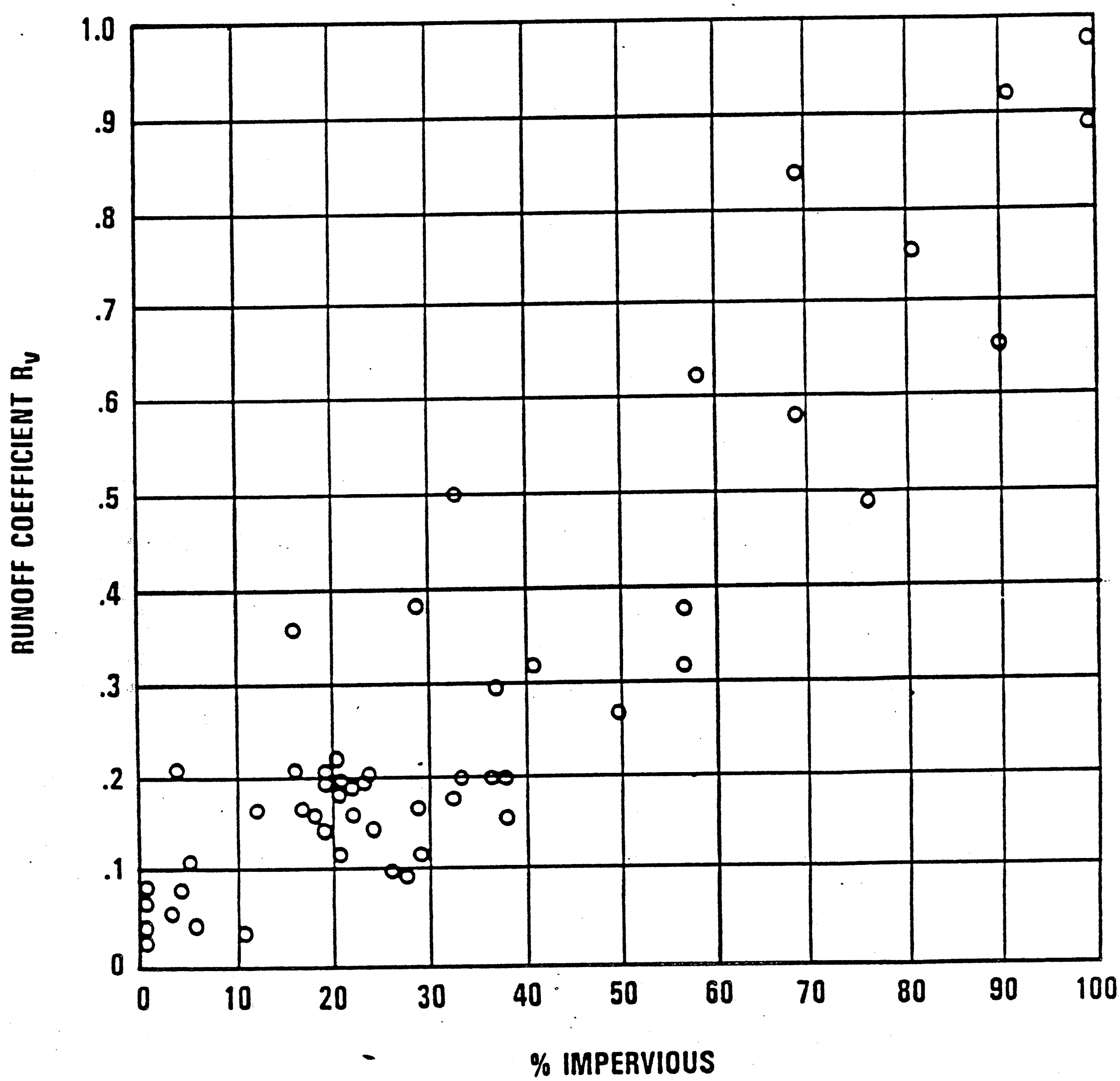


Figure A-4. Relationship between percent impervious area and median runoff coefficient

This information may be used to guide estimates of the surface runoff routed to a detention basin during storm events.

4.0 SETTLING VELOCITIES

The settling velocity of particulates in urban runoff is a key determinant of the efficiency of pollutant removals by sedimentation. Settling velocity measurements were conducted on approximately 50 different runoff samples from seven urban sites. These data may be used to guide estimates in the absence of local settling column study results.

There is a wide range of particle sizes, and hence settling velocities, in any sample of stormwater runoff. This range can be described by a probability distribution of pollutant settling velocities and determined by an appropriate analysis of the data obtained from standard settling column tests, as described further below. When the settling velocity distributions obtained from the NURP studies were analyzed, it was found that there were differences between separate storms at a site, and differences between individual storms at different sites. Site-to-site differences were of the same order as storm-to-storm variations at a particular site, justifying the combination of all data. The result of such an analysis, illustrated by Figure A-5, indicated that it is reasonable to make estimates of "typical" urban runoff settling characteristics and expect that, in an appropriate analysis, short-term variations will average out. This assumption and the relationship shown, proved to work out quite well in the analysis of the performance of nine different detention basins in different parts of the country and differing radically in size.

For analysis purposes, the indicated range of settling velocities can be broken down into five equal fractions that have the characteristics listed in Section 4 of this document.

While the "typical" values provided here are considered to be satisfactory for initial estimates, and for screening analyses, additional settling column studies are encouraged to expand the data base and improve site-specific estimates. The test procedure is quite simple, and utilizes equipment and procedures that have been in general use for many years and frequently applied in water and waste treatment applications. The only difference is the technique suggested for analyzing the data to increase its utility for stormwater runoff applications.

The equipment and procedure are shown schematically by Figure A-6. The settling column, typically lucite and about 6 inches in diameter by 6 feet high, is fitted with a series of sample ports. It is filled with the runoff sample, then small samples are withdrawn from the ports at scheduled intervals of time. Concentrations of pollutants of interest are compared with the initial concentration and the pattern of percent removal versus port depth (H) and time (T) is determined. Since each port depth and sample time corresponds to a settling velocity, each measurement (expressed as percent removal) can be interpreted as the percent of the total that have settling velocities equal to or greater than that characterized by port location and sampling time.

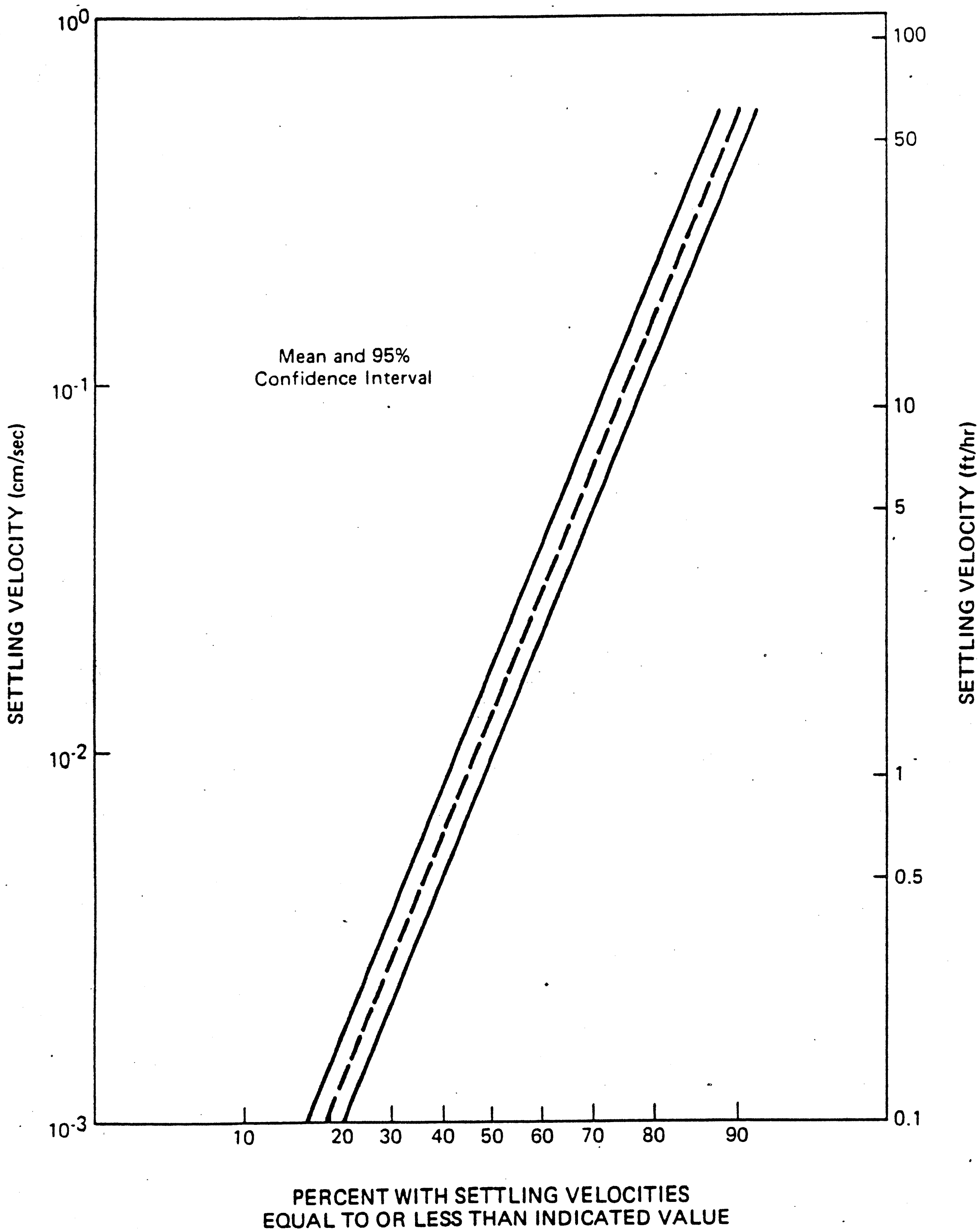
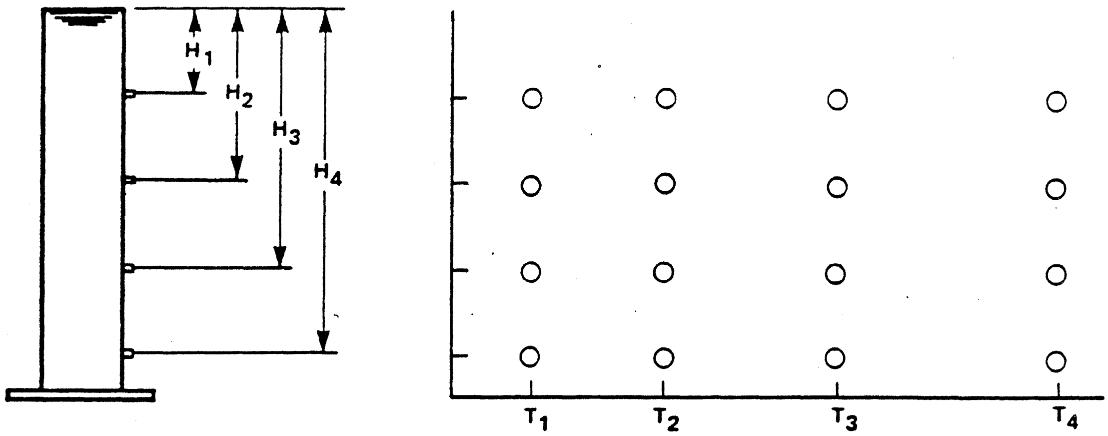


Figure A-5. Probability distribution of settling velocities in urban runoff—typical based on pooled data



O = Data Point - Record % removed based on observed vs. initial concentration

Settling velocity (V_s) for that removal fraction is determined from the corresponding sample depth (h) and time (t)

$$V_s = H/T$$

Observed % removed reflects the fraction with velocities equal or greater than computed V_s

A probability plot of results from all samples describes the distribution of particle settling velocity in the sample

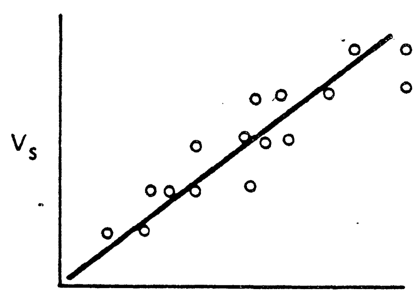


Figure A-6. Estimating settling velocity distributions from settling column tests

Test results are often somewhat erratic because of the sensitivity of analytical tests (especially TSS at low concentrations) and thermal currents and other disturbances in the column. The use of multiple ports and settling times provides data on a range of settling velocities, and provides duplicate measurements for many settling velocities and therefore an opportunity to average out variations inherent in the test procedure.